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(54) Name of the Invention: COMPACT OPTICAL SCANNER DRIVEN BY ELECTROSTATIC FORCE

(57) (Summary)

(Purpose)

The purpose is to provide a compact optical scanner driven by electrostatic force relating to an optical scanner for scanning in uniaxial or biaxial direction, which can be used as a laser radar scanner for writing operations in a facsimile or in a printer, or in the optical information processing field for future applications.

The design provides an ultra-compact type of an optical scanner formed with a driving mechanism comprising a mirror, etc., used for semiconductor processing operations, thus solving the problem of large driving mechanisms and complicated constructions of prior art designs.

(Construction)

The invention provides an ultra-compact optical scanner which can be used for scanning in biaxial direction, comprising a mirror part formed with a silicon substrate enabling displacement in axial direction X and axial direction Y, reflecting semiconductor laser rays;

a beam part formed with a silicon substrate supporting the mirror part on both sides;

a driving electrode part for axial direction X and axial direction Y, positioned opposite the reverse surface of the mirror part;

an electrode substrate, and an insulating film insulating the driving electrodes;

a supporting spacer part determining the gap between the driving electrode part and the mirror part;

further comprising a wiring part for said driving electrodes, wherein the distance to the mirror part is longer than the distance to the driving electrodes;

wherein the electromagnetic force does not have an effect on the mirror part due to a planar formation.

[Figure (a) and (b)]

Figure (a)

1	mirror part
2	silicon substrate
3	beam for scanning in axial direction Y
4	driving electrode for axial direction X
7	supporting spacer part
9	beam for scanning in axial direction Y
60	electrostatic force attracting part for axial direction Y
61	driving electrode for axial direction Y
↑	axis Y
→	axis X

Figure (b)

1	mirror part
5	electrode substrate
6	insulating film
7	supporting spacer part
8	wiring part for driving electrodes

[page 2]

(Scope of the Patent's Claim)

(Claim 1)

A compact optical scanner driven by electrostatic force, characterized by a construction comprising a mirror part formed with a silicon plate displaceable in the direction of axis X, reflecting semiconductor laser light,

wherein the entire construction is integrated with said mirror part, while the thickness of the mirror part is not necessarily identical, comprising a beam (girder) used for scanning in axial direction X, formed with a silicon plate supporting a mirror part on both sides, creating a construction formed so that it is integrated with said beam for scanning in axial direction X from the outer side; forming an integrated construction with said electrostatic force attracting part, said electrostatic force attracting part displaceable in and intersecting axial direction X, and said mirror part;

wherein the thickness of the electrostatic force attracting part is not necessarily identical, comprising a beam for scanning in axial direction Y, formed with a silicon substrate supporting

an electrostatic force attracting part on both sides;

comprising driving electrodes for axial direction X and for axial direction Y arranged opposite the reverse surface of said electrostatic force attracting part and of the mirror part, used in order to operate said mirror part, an electrode substrate formed with said driving electrodes, and an insulating film insulating the driving electrodes, inserted between said mirror part and said electrode driving part, providing support so as to prevent occurrences of mirror deflection due to mirror displacement;

comprising a support spacer part determining the gap between the driving electrodes and the mirror part; as well as a wiring part for said driving electrodes, having a longer distance to the mirror part than to the driving electrodes;

in a compact optical scanner for scanning in biaxial direction formed on the planar level so that the electrostatic force does not have an effect on the mirror part.

(Claim 2)

A compact optical scanner driven by electrostatic force, characterized by a construction comprising a mirror part formed with a silicon plate displaceable in uniaxial direction, reflecting semiconductor laser light,

wherein the entire construction is integrated with said mirror part, while the thickness of the mirror part is not necessarily identical, comprising a beam part formed with a silicon substrate supporting the mirror part on both sides, creating a construction integrated with said beam part;

comprising an electrostatic force attracting part formed with a plurality of elements (groups, stages) used in order to generate torsion induced in the beam part independently from said mirror part;

a driving electrode part positioned opposite said electrostatic force attracting part and said mirror part, an electrode substrate formed with said driving electrodes, and an insulating film which serves to insulate the driving electrodes, inserted between said mirror part and said driving electrodes, providing support so as not to create deflection as a result of mirror displacement;

in a compact optical scanner for scanning in uniaxial direction, comprising a supporting spacer part determining the gap between the driving electrodes and the mirror part.

(Claim 3)

The optical scanner driven by electrostatic force described in claim 1 and claim 2, characterized by the fact that a film preventing reflection on the mirror part is bonded to an

attached glass substrate, wherein a space existing in the mirror part which is sandwiched between the electrode substrate and the glass substrate is vacuum.

(Claim 4)

The optical scanner driven by electrostatic force described in claim 1 and claim 2, characterized by the fact that a plurality of mirrors is arranged within the same plane with a linear or planar arrangement.

(Detailed Explanation of the Invention)

(0001)

(Sphere of Industrial Use)

(0001)

This invention relates to an optical scanner for scanning in biaxial direction or uniaxial direction. The scanner can be used in fields requiring processing of optical information, represented for instance by future optical computing, or for writing with a printer or with a facsimile while using a laser radar scanner in order to probe objects and grasp relevant information.

(0002)

The following is an explanation of an optical scanner according to prior art shown in Figures 8, 9, and 10, which can be used for biaxial scanning. As shown in Figure 8, 9, and 10, number 51 indicates a source of laser light, 52 is a directional mirror for axial direction X, 53 is a directional mirror for axial direction Y, 54 is a polygon mirror, and 55 is a disk typ of a hologram scanner. The following is an explanation of the operation of an optical scanner for scanning in the biaxial direction which has the above described construction. Biaxial scanning can be conducted as shown in Figure 8 because laser light supplied from laser light source 51 will be affected by rotary displacement in axial direction X of mirror 52 and in axial direction Y of mirror 53. This construction can be also combined with a galvanometer construction shown in Figure 9, creating a combined construction including Y-axis direction mirror 52 providing rotational displacement with a galvanometer scanner and with a polygon mirror. Another known construction is the construction shown in Figure 10 in which a Y-direction mirror 53 which creates rotational displacement is combined with a galvanometer scanner and with a disc type hologram scanner 55.

(0003)

Great progress has been achieved in recent years also in research related to micro-

machines, in particular in the area of uniaxial scanning performed with optical scanners. Small, compact types of optical scanners have been manufactured for silicon micro-machining applications, for instance as described in Selected Lectures from the 68th National Conferences of the Japan Association for Mechanical Sciences, Electrostatic Silicon Torsional Oscillation Element [Seidenkei Shirikon Nejiri Shindoshi] (Nakagawa et al., Fuji Electronics), Vol. D, (1990), etc.

(0004)

The following explanation pertains to a compact optical scanner used for uniaxial scanning according to prior art based on Figure 11 and Figure 12. Figure 11 is a diagram showing an external view of an electrostatic torsional oscillation element. Oscillation element 41 comprises a mobile plate 42, a span bound 43, and a frame 44, creating an integrated formation which can be etched from a silicon plate which is 0.3 mm thick. The thickness of mobile plate 42 and of span bound 43 is 20 μm. Silicon oscillation element 41 is formed with a spacer 46 which is inserted in glass plate 45 forming an electrode.

(0005)

Figure 12 shows a profile view of an electrostatic silicon oscillation element indicating its mode of operation. When voltage is applied between an electrode and mobile plate 42 which is supported by an S-shaped span bound 43, electrostatic force will be having an effect between both elements, creating oscillations by an electrostatic attraction in the electrode while span bound 43 forms the axis of mobile plate 42.

(0006)

(Problems To Be Solved By This Invention)

However, when the above described construction is used with an optical scanner for biaxial scanning, this creates a complicated construction consisting of many parts and it is difficult to achieve a compact design in this manner.

(0007)

Although an electrostatic torsional oscillation element is small, it cannot be used for biaxial scanning. Moreover, even when only an optical scanner for uniaxial scanning is taken into consideration, a high driving voltage will be required for an increased scanning angle.

[page 3]

Conversely, when the scanning angle is increased to the limit of the driving voltage, this creates problems such as a reduced mechanical strength of the span bound, etc.

(0008)

The purpose of this invention is to solve the above mentioned problems related to prior art by providing an optical scanner for uniaxial or biaxial scanning with a low driving voltage (for a wide scanning angle), which has a compact design that can be formed with part such as an actuator, a mirror, etc., and which can be used during semiconductor processing.

(0009)

(Means To Solve Problems)

In order to achieve the above mentioned purpose, this invention provides a construction comprising a mirror part formed with a silicon substrate displaceable in the direction of axis X and axis Y, reflecting semiconductor laser light, a beam part formed with a silicon substrate supporting a mirror part on both side, driving electrodes for the Y-axis direction driving and driving electrodes for the X-axis direction arranged opposite the reverse surface of the mirror part in order to drive said mirror part, as well as an electrode substrate formed with said driving electrodes, an insulating film which serves to insulate the driving electrodes deployed between said mirror part and said driving electrodes, forming a supporting spacer part determining the gap between the mirror part and the driving electrode.

Furthermore, because the distance of the wiring part to said driving electrodes is longer than the distance between of the driving electrodes to the mirror part, this creates the construction of an optical scanner enabling scanning in biaxial direction formed on a flat surface without effecting the mirror part, integrated with the construction of the beam part;

provided with an electrostatic force attracting part formed from a plurality of elements (groups, stages) in order to generate torsion in a beam (girder) part independently from the mirror part;

in an optical scanner part enabling scanning in uniaxial direction with a construction formed with driving electrodes arranged opposite said electrostatic force attracting part and said mirror part;

and with a glass substrate which is bonded to a reflection preventing film in the mirror part in a construction wherein a vacuum is created in the mirror part which is sandwiched between the electrode substrate and the glass substrate,;

wherein the mirror of said optical scanner which is driven by electrostatic force has a construction comprising multiple elements arranged on the linear or planar level within the same plane.

(0010)

(Operation)

In accordance with the above described construction of this invention which has a mirror formed on a silicon substrate, when a voltage is applied to the driving electrodes, this makes it possible to conduct biaxial driving operation in the direction of axis X and axis Y, enabling two-dimensional scanning with semiconductor laser rays. This invention thus makes it possible to provide an optical scanner for bidirectional scanning with an extremely compact design of the entire construction. In addition, because the construction supports a plurality of electrostatic force attracting parts, this makes it possible to provide an optical scanner for uniaxial scanning with a wide angle by using a lower voltage than the voltage used according to conventional constructions. Moreover, because the mirror parts of the optical scanner can be operated in a vacuum, this provides for a fast response characteristics. Further, because the mirrors do not use a single array arrangement but rather a linear or planar array arrangement, this makes it possible to achieve a smaller size which could not be achieved according to prior art by providing a completely novel type of an optical scanning device.

(0011)

(Embodiments)

(Embodiment 1)

The following is an explanation of Embodiment 1 of this invention which is based on the reference provided in the figures. Figure 1 shows a view of a compact optical scanner according to an embodiment of this invention which is driven by electrostatic force and which is capable of scanning in biaxial direction. Figure 1 (a) shows a top view and Figure 1 (b) shows a profile view of the scanner.

(0012)

As shown in Figure 1, number 1 indicates a mirror part, 2 is a silicon substrate part, 3 is a beam part, 4 is a driving electrode for axial direction X, 5 is an electrode substrate, 6 is an insulating film, 7 is a supporting spacer part, 8 is a wiring part for driving electrodes, 9 is a beam for scanning in axial direction Y, 60 is a part attracting electrostatic force in axial direction Y, and 61 is a driving electrode for axial direction Y. The construction of mirror part 1 is integrated with beam 3 for scanning in axial direction X. In addition, the other end of beam 3 for scanning in axial direction X is integrated with the construction of electrostatic force attracting part 60 for axial direction Y and this electrostatic force attracting part 60 for axial direction Y is formed integrated with beam 9 for scanning in axial direction Y. Moreover, the other end of beam 9 for scanning in axial direction Y is integrated with the construction of silicon substrate 2 and all of these parts are formed from silicon. Driving electrode 4 for axial direction X is arranged below mirror part 1 and driving electrode 61 for scanning in axial direction Y is arranged below electrostatic force attracting part 60 for axial direction Y and these driving electrode are formed

on electrode substrate 5.

Wiring part 8 for the driving electrodes is formed so that its distance to mirror part 1, etc., is greater than the distance to the driving electrodes and to ensure that the electrostatic force generated by wiring part 8 for the driving electrodes will not affect mirror part 1, the construction is formed with the wiring in the inner part of electrode substrate 8.

(0013)

Insulating film 6 which serves to insulate the driving electrodes and which supports mirror part 1 is formed between electrostatic force attracting part 60 for axial direction Y and mirror part 1, while supporting spacer part 7 is formed so that it determines the gap between the driving electrodes and mirror part 1. Supporting spacer part 7 is formed on electrode substrate 5 and a silicon substrate 2 is bonded to this supporting spacer part 7.

(0014)

The following is an explanation of the operation of a compact optical scanner which is driven by electrostatic force, enabling scanning in biaxial direction with the above described construction.

(0015)

When a voltage is applied to driving electrode 4 for axial direction X of mirror part 1, an electrostatic force will be received and scanning operations will be conducted with light applied in axial direction X, wherein the supporting point is formed by supporting spacer part 7 and beam 3 for scanning in axial direction X. Next, when a voltage is applied to driving electrode 61 for axial direction Y, electrostatic force attracting part 60 for axial direction Y will receive this electrostatic force and scanning operations will be conducted with the light applied in axial direction Y while a supporting point is formed by supporting spacer part 7 and by beam 9 for scanning in axial direction Y. Because mirror part 1 is integrated with electrostatic force attracting part 60 for axial direction Y, the scanning will be conducted with the scanning light in axial direction Y. Scanning can thus be conducted in both axial directions with light which is reflected from mirror part 1.

(0016)

Since in accordance with the above explained embodiment, a voltage is applied to the driving electrodes in axial direction X and axial direction Y with a mirror part 1 which is formed on a silicon substrate 1, this makes it possible to provide a compact type of an optical scanner which is driven by electrostatic force and which enables scanning with the laser light in both axial directions.

(0017)

(Embodiment 2)

This following is an explanation of Embodiment 2 of this invention based on the reference provided in the figures. Figure 2 shows a compact optical scanner according to Embodiment 2 of this direction which is driven by electrostatic force and which enables scanning in 1 axial direction. Figure 2 (a) shows a top view, and Figure 2 (b) shows a profile view of the scanner.

(0018)

As shown in Figure 2, number 1 is a mirror part, 2 is a silicon substrate, 10 is a first beam, 11 is a first electrostatic force attracting part, and 12 is a second beam.

[page 4]

Number 13 indicates a second electrostatic force attracting part, 14 is a beam for the mirror part, 15 is a supporting spacer part, 16 is a an electrode substrate, 17 is an insulating film, 18 is a mirror driving electrode, 19 is a second electrostatic force attracting electrode, and 20 is a driving electrode of the first electrostatic force attracting part. Because mirror part 1 is formed on silicon substrate 2 integrated with beam 14 of the mirror part, beam 14 is formed integrated with the mirror part, and the second electrostatic part 13 and the second beam 12 are formed so as to surround said mirror part 1. In addition, the first beam 10 and the first electrostatic force attracting part 11 are formed to surround said second electrostatic force attracting part 13 in a construction integrated with the second beam 12.

(0019)

As shown in Figure 2 (b), mirror driving electrode 18 is deployed in the part below mirror part 1. In the same manner, driving electrode 19 for the second electrostatic force attracting part 19 is formed in the part below the second electrostatic force attracting part 13, and driving electrode 20 for the first electrostatic force attracting part is formed in the part below the first electrostatic force attracting part 11. These driving electrodes are formed on electrode substrate 16. Insulating film 7 is formed between silicon substrate 2 and electrode substrate 16, and supporting spacer part 15 is formed so as to determine the gap between mirror part 1 and driving electrodes and so as to support mirror part 1. Supporting spacer part 15 is formed on electrode substrate 16 and silicon substrate 2 is bonded to supporting spacer part 15.

(0020)

The above explained construction pertained to a compact optical scanner which is driven by electrostatic force and which enables scanning in 1 axial direction. The following explanation

of the operation of this scanner is based on Figure 3. Figure 3 is a diagram explaining the operation of a compact optical scanner driven by electrostatic force for driving in 1 axial direction.

(0021)

As shown in Figure 3, when a voltage is applied to driving electrode 20 for the first electrostatic force attracting part, electrostatic force is applied to the first electrostatic force attracting part 11 which will adhere to driving electrode 20 for the first electrostatic force attracting part. At this point, the second electrostatic force attracting part 13 and the mirror part 1 will be displaced by the same amount of displacement as the first electrostatic force attracting part 11. Next, when voltage is applied to driving electrode 19 for the second electrostatic force attracting part, electrostatic force will be applied to the second electromagnet force attracting part 13 which will adhere to driving electrode 19 for the second electrostatic force attracting part. At this point, mirror part 1 will be displaced only by a displacement amount which is identical to the second electrostatic force attracting part 13. In addition, when a voltage is applied to mirror driving electrode 18, attracting force will be applied to mirror part 1 which will adhere to mirror driving electrode 18. Due to the above described operation, only mirror part 1 can be driven with a low voltage as a single unit. In addition, this also makes it possible to obtain a wide scanning angle because torsion is generation in very small increments with each of the beam parts while the same voltage is applied.

(0022)

Figure 4 shows a top view of the status of another mirror part shape of a compact optical scanner which is driven by electrostatic force and enables scanning in 1 axial direction according to Embodiment 2 of this invention. As shown in Figure 4, 1 is a mirror part, 21 is the first electrostatic force attracting part, 22 is the second electrostatic force attracting part, 23 is the third electrostatic force attracting part, 24 is the fourth electrostatic force attracting part, and 25 is a supporting spacer part.

(0023)

Also with this shape, when voltage is applied sequentially from the first electrostatic force attracting part to the fourth electrostatic force attracting part, mirror part 1 can be operated with a low driving voltage and a wide scanning angle can be obtained. Moreover, although the present embodiment used a divided construction in which the driving electrodes corresponded to the electrostatic force attracting part, it is also possible to create one electrode for the entire construction. However, although the construction will be more complicated when it is separated, this type of construction makes it possible to exercise the driving control to a higher extent.

(0024)

Because according to the above explained embodiment, a plurality of electrostatic force attracting parts is formed on the periphery of mirror part 1 which is formed on silicon substrate 1, when a voltage is applied sequentially through driving electrodes corresponding to a plurality of electrostatic force attracting parts and said mirror part 1, the driving operations can be conducted with a lower voltage than during driving operations using a single unit of mirror part 1 according to prior art. Furthermore, this also makes it possible to provide a compact optical scanner, driven by electrostatic force and enabling scanning in uniaxial direction while scanning can be attained with a wide scanning angle.

(Embodiment 3)

The following is an explanation of Embodiment 3 of this invention based on the enclosed reference figures. Figure 5 shows a profile view of a compact optical scanner enabling uniaxial or biaxial scanning according to Embodiment 3 of this invention. As shown in Figure 5, 1 is a mirror part, 2 is a silicon substrate, 4 is a driving electrode for axial direction X, 5 is an electrode substrate, 7 is a supporting spacer, 8 is a wiring part for electrode wiring, 30 is a vacuum part, and 31 is a glass substrate.

(0025)

The driving electrode 4 for axial direction X and wiring part 8 of the driving electrode are formed on electrode substrate 5. Moreover, supporting part 7 is formed on top of that, and silicon substrate 2 having a mirror part 1 is bonded to said supporting spacer part 7. Further, the surface side opposite the surface, bonded to supporting spacer part 7 of silicon substrate 2, is joined to glass substrate 31 with an attached reflection preventing film. Anode joining can be used as the joining method to join glass substrate 31 with silicon substrate 2 in a vacuum chamber.

(0026)

When a voltage is applied to the driving electrode with the above mentioned construction, mirror part t 1 will be operated while the response characteristics are improved because the operation is conducted in a vacuum. Also, the mirror surface of mirror part 1 can be maintained free of oxidation. Further, because glass substrate 31 is formed on the surface of mirror part 1, this is represents an effective measure against contamination, etc.

(0027)

As was explained in the above embodiment, because the space existing in one part of the mirror which is sandwiched between the glass plate and the electrode substrate is vacuum, this improves the responsiveness of the operations of the mirror part and it also makes it possible to provide a compact optical scanner capable of scanning in uniaxial or biaxial direction with a strong preventive measure preventing contamination or oxidation of the mirror surface.

(0028)

(Embodiment 4)

The following is an explanation of Embodiment 4 of this invention based on the reference provided in the figures. Figure 6 shows a top view indicating the linear arrangement of a plurality of compact optical scanners enabling scanning in uniaxial direction according to Embodiment 4 of this invention.

(0029)

As shown in Figure 6, 1 is a mirror part, 32 is an optical scanner for scanning in uniaxial direction, 33 is a first mirror array, 34 is a second mirror array, and 37 is a beam supporting scanning in axial direction Y. As shown in Figure 6, optical scanner 32 for scanning in uniaxial direction thus has mirror part 1 which is supported by beam 37 for scanning in axial direction Y with an arrangement creating the first mirror array 33.

[page 5]

In addition, the second mirror array 34 is deployed opposite the first mirror array 33 in the same arrangement as that of the first array of mirror array 33. This makes it possible to initiate operations which will be equivalent to the arrangement of mirror part 1 with a higher density by shifting the arrangement by 1/ 2 pitch in mirror part 1. The design of this arrangement can be used for a writing head in a printer, etc.

(0030)

Figure 7 shows a top view indicating the planar arrangement of a plurality of optical scanners enabling scanning in biaxial scanning direction with a compact scanner according to Embodiment 4 of this invention. As shown in Figure 7, 1 is a mirror part, 35 is an optical scanner for scanning in biaxial direction, and 36 indicates the surface shape arrangement of the optical scanner. The construction of the arrangement of the surface shape of optical scanner 36 is formed with a planner arrangement of optical scanner 36 for biaxial scanning which has a mirror part 1 in the center. This surface shape arrangement of the optical scanner 36 can be used in a very thin display, or the use as an optical information processing element is also conceivable for the purposes of optical computing.

(0031)

As was explained above, this embodiment provides a novel type of a compact optical scanner device through a planar or linear arrangement of a plurality of optical scanners in a biaxial or uniaxial scanner which was not available with a single optical scanner.

(0032)

(Effect of the Invention)

As was explained above, this invention provides a construction comprising a mirror part formed with a silicon substrate which can be displaced in the axial direction of axis X and axis Y, reflecting semiconductor laser rays, and a supporting beam part is formed with a silicon substrate supporting the mirror part from both sides,

wherein in order to operate said mirror part, driving electrodes for driving in axial direction X and in axial direction Y are deployed opposite the reverse surface of the mirror part, comprising an insulating film insulating the driving electrodes, inserted between said mirror part and said driving electrodes, and a supporting spacer part determining the gap between the driving electrode part and the mirror part.

Further, the distance between the wiring part and said driving electrode part is longer than the distance from the driving electrodes to the mirror in a construction of an optical scanner enabling scanning in biaxial direction formed with a flat surface shape wherein the electrostatic force is not affecting the mirror part, formed in an integrated construction with the supporting beam part.

Torsion is thus generated in the beam part independently from the mirror part in a construction comprising a plurality of (groups, stages) of the formed electrostatic force attracting parts in an optical scanner enabling scanning in uniaxial direction with the construction of the formed driving electrodes deployed opposite said electrostatic force attracting part and said mirror part, while a glass substrate is bonded to a film preventing reflection on the surface of the mirror part.

The construction also comprises vacuum created in a space in the mirror part sandwiched between the glass substrate and the electrode substrate, while the mirrors of said optical scanner which is driven by electrostatic force are arranged in a linear or planar arrangement of a plurality of elements constructed within the same plane.

(0033)

As a result of the above described construction, when a voltage is applied as a driving voltage to the mirror formed on the silicon substrate, enabling biaxial scanning in axial direction X and axial direction Y, semiconductor laser light can be used for two dimensional scanning. This makes it possible to provide an optical scanner for scanning in biaxial direction which has an ultra-compact construction. In addition, because the construction supports a plurality of electrostatic force attracting parts, this makes it possible to provide an optical scanner for uniaxial scanning which can be used with a wider angle and with a lower voltage than according to prior art constructions. Moreover, a high response speed is enabled thanks to the fact that the

mirror parts of this optical scanner can be operated in vacuum. Further, since this is not a single mirror part but an array which is arranged in a linear or planar arrangement, this makes it possible to provide a completely novel type of a compact optical scanner not available according to prior art as a device which can be used in the optical information field, or as a writing head in a printer, etc.

(Brief Explanation of Figures)

(Figure 1)

(a) A top view of a compact optical scanner which is driven by electrostatic force enabling scanning in biaxial scanning direction according to Embodiment 1 of this invention;

(b) a profile view of a compact optical scanner which is driven by electrostatic force enabling scanning in biaxial scanning direction according to the same embodiment.

(Figure 2)

A top view of a compact optical scanner which is driven by electrostatic force enabling scanning in uniaxial scanning direction according to Embodiment 2 of this invention;

(b) a profile view of a compact optical scanner which is driven by electrostatic force enabling scanning in uniaxial scanning direction according to the same embodiment.

(Figure 3)

A diagram explaining the operation of a compact optical scanner driven by electrostatic force enabling scanning in uniaxial scanning direction according to the same embodiment.

(Figure 4)

A top view indicating another mirror shape of a compact optical scanner driven by electrostatic force enabling scanning in uniaxial direction according to the same embodiment.

(Figure 5)

A profile view of a compact optical scanner enabling uniaxial or biaxial scanning according to Embodiment 3 of this invention.

(Figure 6)

A top view indicating a detail of the linear arrangement of a plurality of compact optical scanners enabling scanning in uniaxial direction according to Embodiment 4 of this invention.

(Figure 7)

A top view indicating the detail of the planar arrangement of a plurality of compact optical scanners enabling scanning in biaxial direction according to the same embodiment.

(Figure 8)

A perspective view of a scanner enabling scanning in biaxial direction with a conventional galvano meter scanner method.

(Figure 9)

A perspective view explaining the concept of an optical scanner for scanning in biaxial direction with a galvanometer scanner and polygon mirror according to prior art.

(Figure 10)

A perspective view explaining the concept of an optical scanner for scanning in biaxial direction with a galvanometer scanner and hologram scanner according to prior art.

(Figure 11)

An external perspective view of a silicon torsion oscillation element of the electrostatic type according to prior art.

(Figure 12)

A profile view indicating the operating status of a silicon torsion oscillation element of the electrostatic type according to prior art.

(Explanation of Codes)

1 mirror part,
2 silicon substrate,
3 beam for scanning in axial direction X,
4 electrode for driving operations in axial direction X,
5 electrode substrate,
6 insulating film,
7 supporting spacer part,
8 wiring part for driving electrodes,
9 supporting beam for scanning in axial direction Y,
10 the first supporting beam,

[page 8]

11 the first electrostatic force attracting part,
12 the second supporting beam,
13 the second electrostatic force attracting part,
14 mirror part supporting beam,
15 supporting spacer part,
16 electrode substrate,
17 insulating film,
18 mirror driving electrode,
19 the second electrostatic force attracting part driving electrode,
20 the first electrostatic force attracting part driving electrode,
21 the first electrostatic force attracting part,
22 the second electrostatic force attracting part,
23 the third electrostatic force attracting part,
24 the fourth electrostatic force attracting part,
25 supporting spacer part,
30 vacuum part,
31 glass substrate,
32 optical scanner for scanning in uniaxial direction,
33 the first mirror array,
34 the second mirror array,
35 optical scanner for scanning in biaxial direction,
36 optical scanner with surface shape arrangement,
37 supporting beam for scanning in Y direction,
41 oscillation element,
42 mobile plate,
43 span bound,
44 frame,
45 glass substrate,
46 spacer,
51 source of laser light,
52 mirror for axial direction X,
53 mirror for axial direction Y,
54 polygon mirror,
55 disk type hologram scanner,
60 electrostatic force attracting part in axial Y,
61 driving electrode for axial direction Y.

Figure 1 (a), (b), Figure 2, (a), (b), Figure 4 and Figure 6.

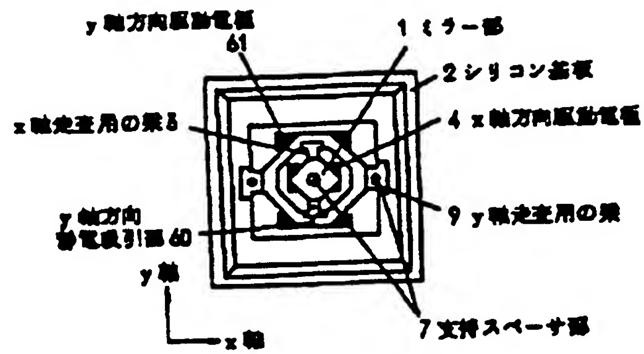
(Figure 1 a and b)

(a)

1 mirror part
2 silicon substrate
3 beam for scanning in Y direction
4 driving electrode for X direction
7 supporting spacer part
60 electrostatic force attracting part for axial direction Y
↑ Y direction
→ X direction

【図1】

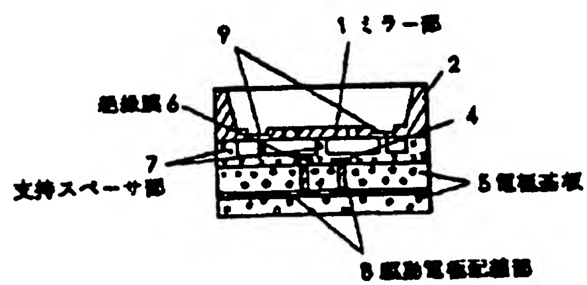
(a)



(b)

1 mirror part
5 electrode substrate
6 insulating film
7 supporting spacer part

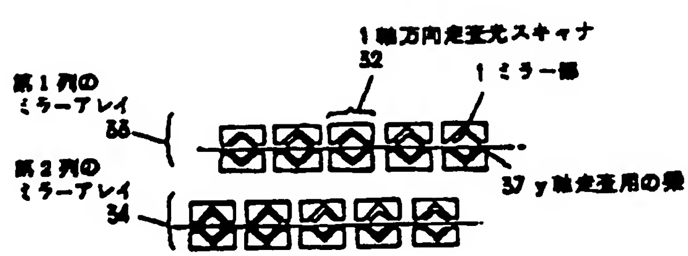
(b)



(Figure 6)

1 mirror part
2 second mirror array
32 optical scanner for scanning in uniaxial direction
33 first mirror array
34 second mirror array
37 beam for scanning in axial direction Y

【図6】



(Figure 2)

(a)

1 mirror part
2 silicon substrate
10 the first beam
11 the first electrostatic force attracting part
12 the second beam
13 the second electrostatic force attracting part
14 beam for the mirror part
<–> scanning direction

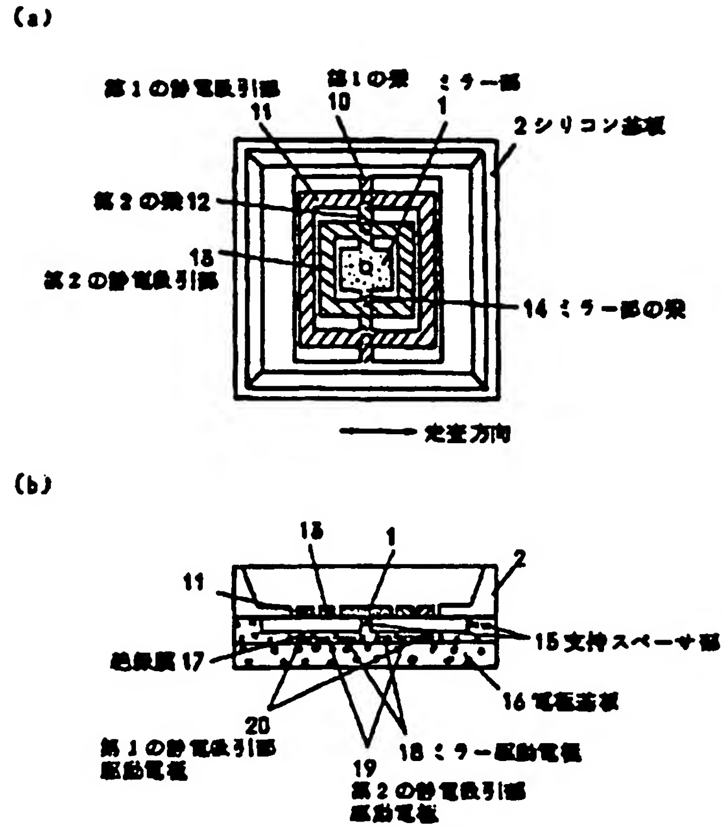
(b)

15 supporting spacer part
16 electrode substrate
17 insulating film
18 mirror driving electrode
19 the second electrostatic force attracting part
20 the first electrostatic force attracting part

【図2】

(a)

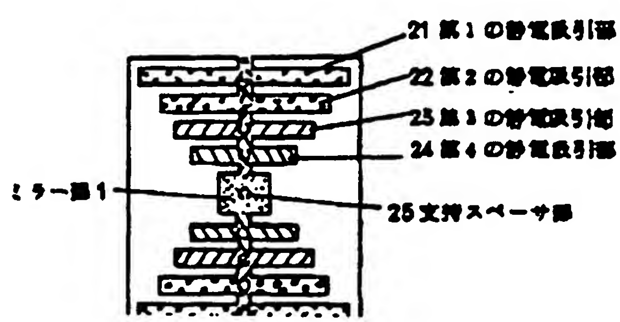
(b)



(Figure 4)

1 mirror
21 the first electrostatic force attracting part
22 the second electrostatic force attracting part
23 the third electrostatic force attracting part
24 the fourth electrostatic force attracting part
25 supporting spacer part

【図4】

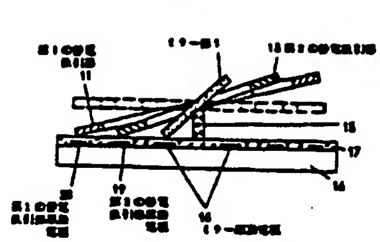


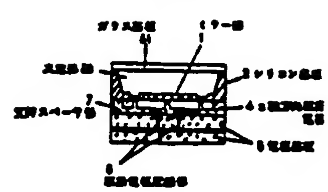
[page 7]

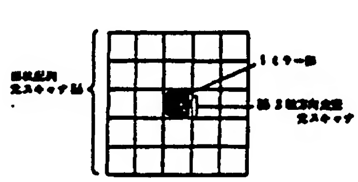
Figure 3, Figure 5, Figure 7, Figure 8, Figure 9, Figure 10

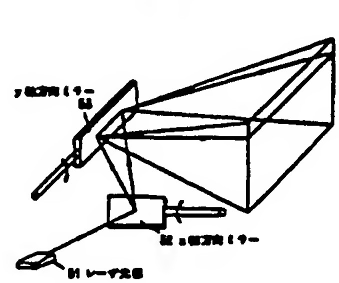
[page 8]

Figure 12









(Figure 3)

1 mirror part
11 the first electrostatic force attracting part
13 the second electrostatic force attracting part
18 mirror driving electrode
19 the second electrostatic force attracting part driving electrode
20 the first electrostatic force attracting part driving electrode

(Figure 5)

1 mirror part
2 silicon substrate
4 driving electrode for axial direction X
5 electrode substrate
7 supporting spacer part
8 driving electrode substrate
30 vacuum part
31 glass substrate

(Figure 7)

1 mirror part
35 optical scanner for scanning in biaxial direction
36 surface shape arrangement of optical scanner

(Figure 8)

51 laser light source
52 mirror for axial direction X
53 mirror for axial direction Y

(Figure 9)

54 polygon mirror

(Figure 10)

53 disk type of hologram scanner

(Figure 11)

41 oscillation element
45 glass substrate
46 spacer

[page 8]

(Figure 12)

42 mobile plate
44 frame
46 spacer
45 glass substrate